

Technical Report 5-20387 & 5-20388  
Contract No. DAAH01-98-D-R001  
Delivery Order No. 28

**Research and Evaluation  
of MEMS Technologies  
(5-20387 & 5-20388)**

Final Technical Report for Period  
12 November 98 through 30 January 1999

October 1999

Prepared by:

Gary A. Maddux

Research Institute  
The University of Alabama in Huntsville  
Huntsville, Alabama 35899

Prepared for:

U.S. Army Aviation & Missile Command  
Redstone Arsenal, AL 35898  
Attn.: Ms. Barbara Robertson

20000309 063

DTIC QUALITY INSPECTED 3

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

<b>1. AGENCY USE ONLY (Leave blank)</b>		<b>2. REPORT DATE</b> October 99	<b>3. REPORT TYPE AND DATES COVERED</b> Final Report: 12 Nov 98 thru 30 Jan 99	
<b>4. TITLE AND SUBTITLE</b>  Research and Evaluation of MEMS Technologies			<b>5. FUNDING NUMBERS</b>	
<b>6. AUTHOR(S)</b>  Gary A. Maddux				
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Univ. of Alabama in Huntsville Huntsville, AL 35899			<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  5-20387 & 5-20388	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  AMSAM-RD-WS-DP (B. Robertson) U.S. Army Aviation & Missile Command Redstone Arsenal, AL 35898			<b>10. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>	
<b>11. SUPPLEMENTARY NOTES</b>				
<b>12a. DISTRIBUTION/AVAILABILITY STATEMENT</b>  Approved for Public Release; Distribution is unlimited.			<b>12b. DISTRIBUTION CODE</b>  A	
<b>13. ABSTRACT (Maximum 200 words)</b>  New micro-electro-mechanical systems (MEMS) technologies are emerging in the research community as a low cost guidance solution for missiles. DARPA and AMCOM are currently investigating this emerging technology for weapon systems that should have positive impacts on the producibility, operations and support of future missile designs. It is essential to evaluate the U.S. manufacturing base to determine MEMS performance characteristics, design, trades, and manufacturing challenges to support research activities. AMCOM required engineering support in performing assessments on MEMS technologies. The Systems Management and Production Laboratory at The University of Alabama in Huntsville (UAH) Research Institute (RI) was tasked to provide this engineering support and analytical capability.				
<b>14. SUBJECT TERMS</b>  MEMS technology			<b>15. NUMBER OF PAGES</b> 2	
			<b>16. PRICE CODE</b>	
<b>17. SECURITY CLASSIFICATION OF REPORT</b>	<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b>	<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b>	<b>20. LIMITATION OF ABSTRACT</b>	

PLEASE CHECK THE APPROPRIATE BLOCK BELOW

DAO# \_\_\_\_\_

☐ \_\_\_\_\_ copies are being forwarded. Indicate whether Statement A, B, C, D, E, F, or X applies.

☒ DISTRIBUTION STATEMENT A:  
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

☐ DISTRIBUTION STATEMENT B:  
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES  
ONLY; (indicate Reason and Date). OTHER REQUESTS FOR THIS  
DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT C:  
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND  
THEIR CONTRACTS (Indicate Reason and Date). OTHER REQUESTS  
FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT D:  
DISTRIBUTION AUTHORIZED TO DoD AND U.S. DoD CONTRACTORS  
ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO  
(Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT E:  
DISTRIBUTION AUTHORIZED TO DoD COMPONENTS ONLY; (Indicate  
Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT F:  
FUTHER DISSEMINATION ONLY AS DIRECTED BY (Indicate Controlling DoD Office  
and Date) or HIGHER DoD AUTHORITY.

☐ DISTRIBUTION STATEMENT X:  
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES  
AND PRIVATE INDIVIDUALS OR ENTERPRISES ELIGIBLE TO OBTAIN EXPORT-CONTROLLED  
TECHNICAL DATA IN ACCORDANCE WITH DoD DIRECTIVE 5230.25. WITHHOLDING OF  
UNCLASSIFIED TECHNICAL DATA FROM PUBLIC DISCLOSURE, 6 Nov 1984 (indicate date of  
determination). CONTROLLING DoD OFFICE IS (Indicate Controlling DoD Office).

☐ This document was previously forwarded to DTIC on \_\_\_\_\_ (date) and the  
AD number is \_\_\_\_\_.

☐ In accordance with provisions of DoD instructions. The document requested is not supplied because:

☐ It will be published at a later date. (Enter approximate date, if known).

☐ Other. (Give Reason)

DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly above. Technical Documents must be assigned distribution statements.

GARY A. MADDUX

Print or Type Name

Gary A. Maddux 11 Oct 99  
Authorized Signature/Date

256 876 0828

Telephone Number

## PREFACE

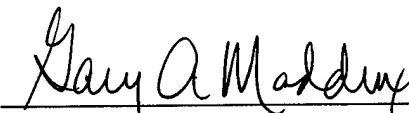
This technical report was prepared by the staff of the Research Institute, The University of Alabama in Huntsville. The purpose of this report is to provide documentation of the work performed and results obtained under Delivery Order 28 of AMCOM Contract No. DAAH01-98-D-R001. Mr. Gary Maddux was the principal investigator. Ms. Barbara Robertson, Weapon Sciences Directorate, Research, Development, and Engineering Center, U.S. Army Aviation & Missile Command, provided technical coordination. Ms. Robertson also provided technical expertise and insights in MEMS technology.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision unless so designated by other official documentation.

Except as provided by the Contract Data Requirements List DD Form 1423, hereof, the distribution of any contract report in any state of development or completion is prohibited without the approval of the Contracting Officer.

Prepared for: Commander  
U.S. Army Aviation & Missile Command  
Redstone Arsenal, AL 35898

I have reviewed this report, dated October 1999 and the report contains no classified information.

  
Principal Investigator

## TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
2.0	OBJECTIVES .....	1
3.0	STATEMENT OF WORK .....	1
4.0	DESCRIPTION OF WORKSHOP.....	2
5.0	CONCLUSIONS AND RECOMMENDATIONS .....	2

## **1.0 Introduction**

New micro-electro-mechanical systems (MEMS) technologies are emerging in the research community as a low cost guidance solution for missiles. DARPA and AMCOM are currently investigating this emerging technology for weapon systems that should have positive impacts on the producibility, operations and support of future missile designs. It is essential to evaluate the U.S. manufacturing base to determine MEMS performance characteristics, design, trades, and manufacturing challenges to support research activities.

The Systems Engineering and Production Directorate has the mission and function of evaluating new technologies and determining the impacts of same on the producibility and supportability of AMCOM missile systems. AMCOM required engineering support in performing assessments on MEMS technologies. The Systems Management and Production Laboratory at The University of Alabama in Huntsville (UAH) Research Institute (RI) was tasked to provide this engineering support and analytical capability.

## **2.0 Objective**

The objective of this research task was to research and evaluate the state-of-the-technology of MEMS for missile applications. The outcome of this research was a body of knowledge that can be disseminated throughout the DOD and incorporated in the appropriate weapon systems planning. UAH conducted research to identify and categorize MEMS technologies based on the potential for DoD weapons applications and manufacturing technology maturity.

## **3.0 Statement of Work**

The statement of work, as outlined in delivery order 28, was as follows:

UAH shall provide the personnel, resources, expertise and materials required to perform the following efforts:

**3.1** UAH shall conduct research to assess technology requirements, status, and needed militarily beneficial advancements in MEMS based Inertial Navigation Systems (INS).

**3.2** UAH shall conduct research to identify candidate technology maturation gaps and candidate technology demonstration platforms, and identify host platform environmental factors (missile requirements) that must be considered in technology development.

**3.3** UAH shall solicit inputs from the defense, industrial and academic community on the subjects in Paragraphs 3.1 and 3.2. It is envisioned that these inputs shall be provided in electronic format, and shall be available for appropriate distribution.

**3.4** The Government will host a workshop on the findings of the research conducted in Paragraphs 3.1 and 3.2 during December 1998. UAH shall participate in the selection process of the topics to be presented.

#### **4.0 Description of Workshop**

The work performed on this task led directly to the Workshop on MEMS Technology, which was held at the Sparkman Center Auditorium in December 1998. The objective of this workshop was to review the progress of MEMS technologies applicable to DoD weapon systems.

#### **5.0 Conclusion and Recommendations**

During the time frame allocated by the delivery order, members of the UAH Applied Research Program, with the cooperation of representatives from AMCOM SEPD and Missile Guidance, performed an analysis and evaluation of MEMS technologies. Results of these efforts were presented at a locally held workshop. Detailed findings can be found in the proceedings of that workshop, which was compiled by UAH and delivered under separate cover.